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(54) IMPROVEMENTS IN OR RELATING TO HIGH-CURRENT ELECTRICAL SWITCHES EMPLOYING LIQUID METAL

(71) We, GEC-ELLIOTT AUTOMATION LIMITED, of Elstree Way, Borehamwood, Hertfordshire, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to high-current electrical switches and particularly to such switches in which electrical connection between spaced contact surfaces of two conductors is effected by bridging the gap therebetween with liquid metal.

It is an object of the present invention to provide a high-current electrical switch which is stable in operation and durable despite repeated making and breaking of very large currents.

According to the present invention, a high current electrical switch comprises two spaced-apart, fixed contacts, a mass of liquid metal of which gallium is at least a constituent, said liquid metal being contained partly by a movable contact so as to be movable with it, said movable contact being movable into contact with one of said fixed contacts in the closed condition of the switch, and the arrangement being such that closing movement of said movable contact causes said mass of liquid metal to bridge said fixed contacts.

Preferably, one of the fixed contacts is of annular form, coaxial with and surrounding the movable contact to which the annular contact is sealed by a flexible bellows to form a reservoir for the liquid metal, the movable contact being immersed in the liquid metal as the bellows is compressed on closing the switch.

Suitable liquid alloys are alloys comprising gallium with one or more other metals which are substantially inert in the ambient atmosphere, and which alloys are liquid at the ambient temperature of the switch. Preferred examples of such other metals include indium and tin.

Gallium and its alloys are preferred to mercury, which has been used in previous liquid metal switches, because of the toxic nature of mercury, its comparatively high vapour pressure, and the non-conductive property of its oxide, which also tends to cause mercury to de-wet on certain metals such as copper. Consequently, mercury could only be used in enclosed spaces sealed from the atmosphere to prevent oxidation and evaporation of the mercury.

Gallium, on the other hand, is non-toxic and has a comparatively low vapour pressure and metallically wets many metals by forming a surface alloy. Gallium oxide mixes easily with the metal to form a conducting material which adheres to copper contact surfaces and passivates the surface of the liquid metal.

It is well known that an electromechanical force is produced on a current carrying conductor if a magnetic field perpendicular to the direction of the current is applied to the conductor. The direction of this force is perpendicular to both the direction of the current and the magnetic field, and if the conductor is a liquid metal this force will act to pump the liquid metal in the direction of the force.

In the case of high current electric switches of the kind in which electrical connection between spaced contact surfaces of two conductors is effected by bridging the gap therebetween with liquid metal, the magnetic field generated by the conductors carrying current to and from the contacts bridged by the liquid metal is considerable and produces an electromechanical force on the liquid metal which may act in a direction to expel the liquid metal from the gap between the contact surfaces. This would require a

sizeable hydrostatic head of liquid metal to balance the electromechanical force and maintain a bridging contact. Sometimes a continuous stirring effect is caused and additional power losses ensue.

This is disadvantageous in the case of electric switching devices of this kind as it requires the displacement of a considerable quantity of liquid metal to make and break contact and is generally unstable in operation.

It is a further object of the present invention to provide a high current electric switch wherein the above mentioned disadvantages are overcome or at least substantially reduced.

The switch may include flux shield means arranged in use to surround the contact gap to shield the current-carrying liquid metal therein from stray magnetic flux.

The flux shield may be movable into and out of an operative position in which it surrounds the contact gap, conveniently being coupled to switch actuating means operable to displace the liquid metal into the contact gap, the arrangement being such that the flux shield is moved into and out of its operative position as the actuating means is operated to close and open the switch respectively.

The invention will now be further described, by way of example only, with reference to the accompanying drawing showing a sectional side view of a switch embodying the invention.

Referring to the drawing, a high current switch in accordance with the present invention comprises concentric inner and outer solid copper contacts 125, 126 spaced from one another and relatively fixed by an inner one another and relatively fixed by an annular insulating collar 127 of ceramic or other suitable material.

The inner contact comprises a circular disc portion 128 having a central cylindrical contact portion 129 depending downwardly therefrom, and the outer contact 126 comprises an annular flange portion 131 from which depends a hollow cylindrical wall portion 132 from which depends a hollow cylindrical wall portion 132 which concentrically surrounds the contact portion 129 of the inner conductor and is spaced therefrom by an annular radial gap 134.

A reservoir for containing a pool of liquid metal 133 is provided by a flexible bellows 136, e.g. of stainless steel, titanium or other corrosion resistant material, hermetically sealed between the lower end of the wall portion 132 of one contact and a metal, e.g. stainless steel, movable contact 138 shaped to conform with the internally bevelled lower end of the wall portion 132. The liquid metal is a liquid alloy of gallium, e.g. gallium/indium.

The annular collar 127, in addition to serving as an insulating spacer, also provides an airtight seal between the two contacts 125, 126, the interior of the switch including an atmosphere of an inert blanket gas or being evacuated to protect the liquid metal from the external atmosphere.

The switch is shown in its open condition in which the movable contact 138, is in its lower position and the level (139) of liquid metal is not sufficiently high to bridge the radial gap 134 between the two contacts 125, 126. To close the switch, actuating means (not shown) e.g. a pneumatic cylinder, is caused to move the contact 138 upwards to the position shown in dotted lines, compressing the bellows 136 and displacing the liquid metal to the level 140 shown in dotted lines in which it bridges a substantial portion of the radial contact gap 134. In its upper position the contact 138 fits closely within the lower end of the outer wall portion 132 and thus effectively reduces the quantity of liquid metal required.

Again the current path within the switch, as indicated by arrows, is completely symmetrical and coaxial with respect to the radial contact gap 134. At the lower end, the current path can be seen to be from the inner fixed contact, through a connecting layer of liquid metal, through the movable contact 138 to the outer fixed contact 126. Thus although the passage of current through the switch when closed will produce an electromechanical force on the current carrying liquid metal in the gap, acting downwardly to tend to expel it therefrom, this force will be completely symmetrical with respect to the gap. Thus, because the liquid metal is mechanically trapped within the gap by the sealed reservoir 136, this force will not cause any undesirable instability of the liquid metal in the gap 134.

A flux shield of ferromagnetic material, not shown, may be provided to shield the current-carrying liquid metal in the gap 134 against the effects of stray magnetic fluxes generated externally of the switch. This may be fixed permanently in an operative position surrounding the gap 134 or may be movable, independently, or in conjunction with the movement of the reservoir 136, into and out of its operative position. In the latter case the flux shield may be fixed to the contact 138 for movement therewith, or mechanically coupled to the reservoir through means for amplifying its movement if the stroke of the reservoir is insufficient.

The contacting surfaces of the contacts 125, 126 may be lined with tungsten or molybdenum to protect them from the effects of arcing or erosion and also permanently wetted with a coating of the liquid metal, for example liquid gallium/indium by the

following method to reduce contact resistance and increase contact life.

The wetting of the contact surfaces may be effected by 'washing' the contact surface areas to be treated with a (e.g. 50%) solution of hydrochloric acid to remove surface oxide, and brushing, with glass-fibre brush for example, the liquid metal onto the contact surface while the acid is still present until excess liquid metal drips off. The acid solution is then removed from the surface and an oxide coating forms on the liquid metal surface and serves to passivate it.

WHAT WE CLAIM IS:—

1. A high current electrical switch comprising two spaced-apart, fixed contacts, a mass of liquid metal of which gallium is at least a constituent, said liquid metal being contained partly by a movable contact so as to be movable with it, said movable contact being movable into contact with one of said fixed contacts in the closed condition of the switch, and the arrangement being such that closing movement of said movable contact causes said mass of liquid metal to bridge said fixed contacts.

2. A switch according to Claim 1, wherein one of said fixed contacts is of annular form, coaxial with and surrounding said movable contact to which the annular contact is sealed by a flexible bellows to form a reservoir for the liquid metal, the movable contact being immersed in the liquid metal as the bellows is compressed on closing the switch.

3. A switch according to Claim 1 or Claim 2 wherein said liquid metal comprises an alloy of gallium and at least one of the metals indium and tin.

4. A high-current electrical switch substantially as hereinbefore described with reference to the accompanying drawing.

For the Applicants,
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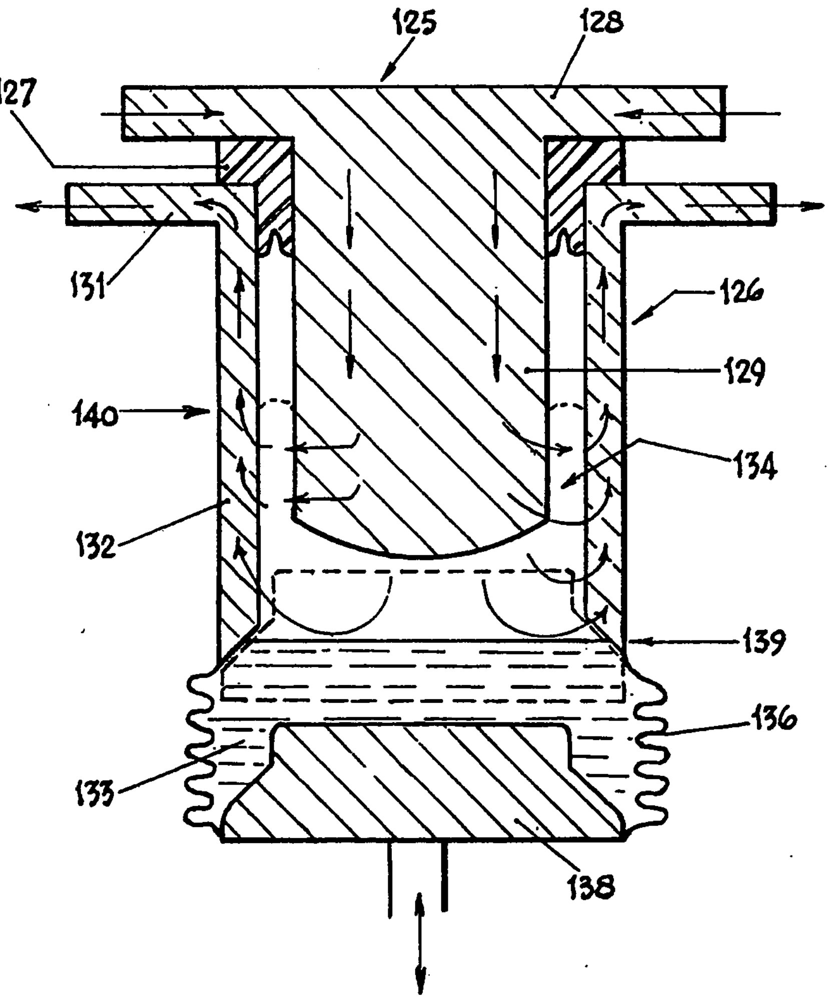
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